ACCURACY OF ESTIMATING FEMORAL AND TIBIAL MECHANICAL AXES FROM SIMULATED LONG STANDING AP RADIOGRAPHS

Rahul Khare PhD[1]*, Branislav Jaramaz PhD[1]

[1]Blue Belt Technologies, Pittsburgh, PA 15222, USA, {rkhare,branko}@bluebelttech.com

INTRODUCTION

Postoperative radiological assessment is used to evaluate the success of knee replacement procedures. Load-bearing long-standing anterior-posterior (AP) radiographs are typically used for this assessment. For knee replacement procedures the five landmarks that are identified are: 1) hip center; 2) femoral knee center; 3) tibial knee center; 4) medial malleolus; and 5) lateral malleolus. These landmarks are used to identify the femoral and tibial reference mechanical axes. However, variations in the x-ray acquisition process and foot rotation can lead to errors in this assessment. In the past, researchers have studied the effect of foot rotation and flexion on estimation of knee alignment [1,2]. In our study, the use of digitally reconstructed radiographs (DRRs) allows us to vary the x-ray acquisition parameters and observe the effect of these changes to estimations of the mechanical axes. We also measured the inter-user variability in these measurements.

MATERIALS AND METHODS

For our study, we first collected 10 hip-toe CT images from cadavers. Using a software application developed using the VTK and ITK libraries, the following five bone landmark points were identified in each of the CT volumes: 1) hip center; 2) femoral knee center; 3) tibial knee center; 3) medial malleolus; and 5) lateral malleolus. In these landmarks, the hip center was obtained by fitting a sphere to the femoral head. The femoral knee center was obtained as the intersection of the distal femur with the femoral shaft axis. The tibial knee center was identified as the center of the proximal tibia approximated using the sagittal, coronal and axial views of the articular surface. The bi-malleolar technique was used to identify the ankle center using the two malleolar points. The "RayCastInterpolateImageFunction" filter from the ITK library was then used to vary the projection center and the rotation angle to project the CT images and obtain six sets of long-standing DRRs (Fig. 1) [3]. Two users were asked to mark the landmark points in every DRR [4]. Groundtruth DRRs containing the projected positions of the landmark points were also obtained for each x-ray acquisition parameter (Fig. 2). The user-marked and groundtruth landmark points were used to obtain the femoral and tibial mechanical axes. Semi-automated scripts were then used to obtain the angular error in the axes obtained from the manually-measured landmark points.

RESULTS

We obtained the following ranges for the measurement root mean square (rms) errors for the five landmarks (in mm): 1) User 1: [1.68, 2.00], [4.64, 7.75], [2.37, 3.00], [1.98, 5.88], and [4.67, 9.63]; and 2) User 2: [1.34, 1.86], [6.46, 10.03], [1.78, 2.61], [1.85, 8.22], and [2.78, 5.26]. We observe from the results that the measurements for the malleolus are most affected due to foot rotation. Also, a larger error was observed in the femoral knee center measurement. On further analysis, we found that the high femoral knee center errors were caused in those cases in which the angle of the epicondylar axis with the projection plane was large. We also found that even though there were large errors in the landmark positions, these

errors did not significantly affect the estimation of the mechanical axis of the femur and the tibia. Thus, the errors in the femoral and tibial mechanical axis were small with the rms ranges as follows: 1) User 1: [0.47, 0.86], and [0.19, 0.29] and 2) User 2: [0.66, 1.07], and [0.16, 0.30].

CONCLUSIONS

We conclude from the results that high errors in measurements of landmark points from AP x-rays do not translate into high errors in the estimation of femoral and tibial mechanical axis. Thus, the long standing AP radiographs can be used to accurately estimate the femoral and tibial mechanical axes.

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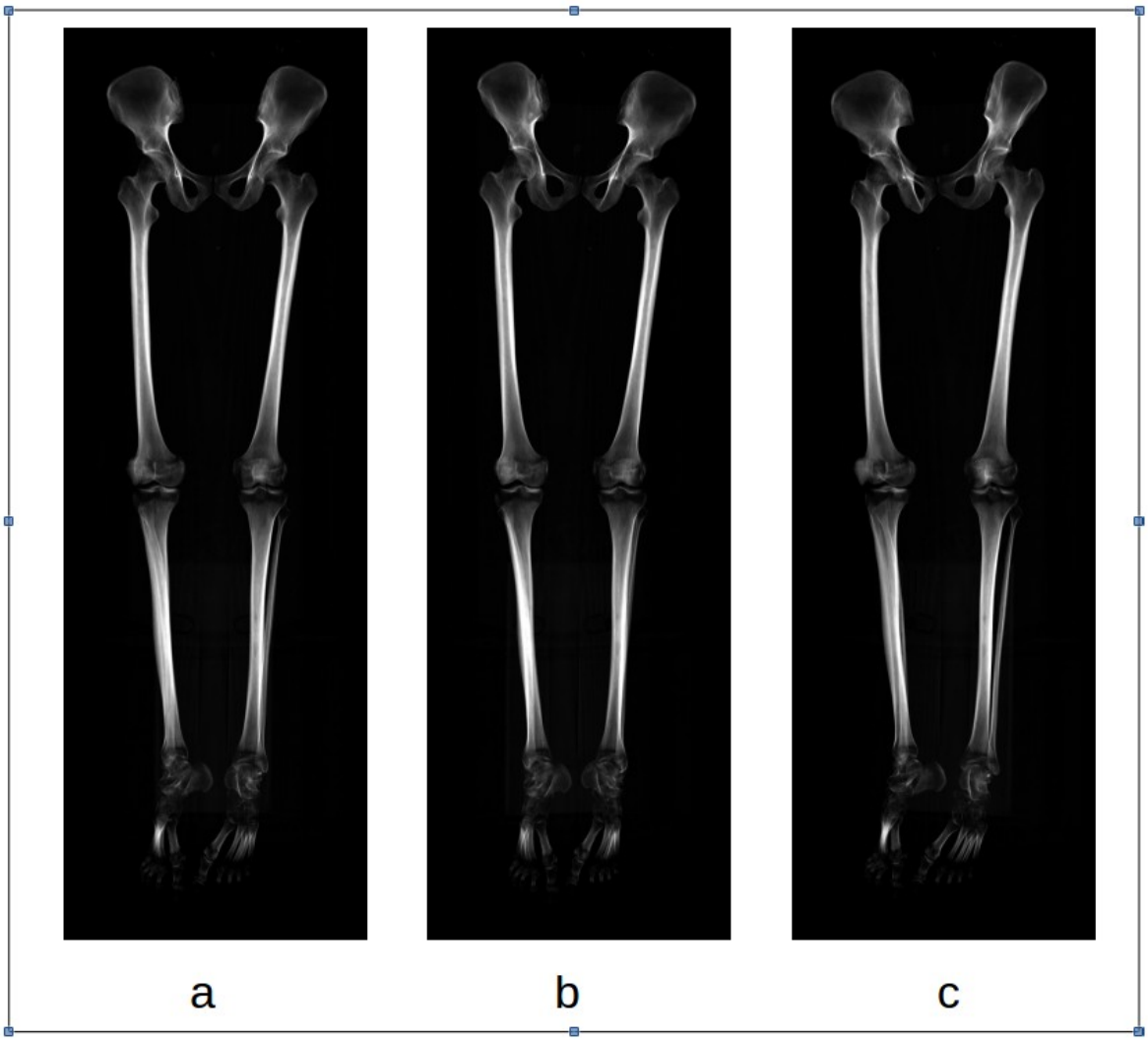

Figure 1: DRRs (case GL_1302335) obtained under under varying foot rotation (a: foot rotation= 0, b: foot rotation = -10 degrees, c: foot rotation = 10 degrees).

DISCLOSURES

Both the authors are employees of Blue Belt Technologies.

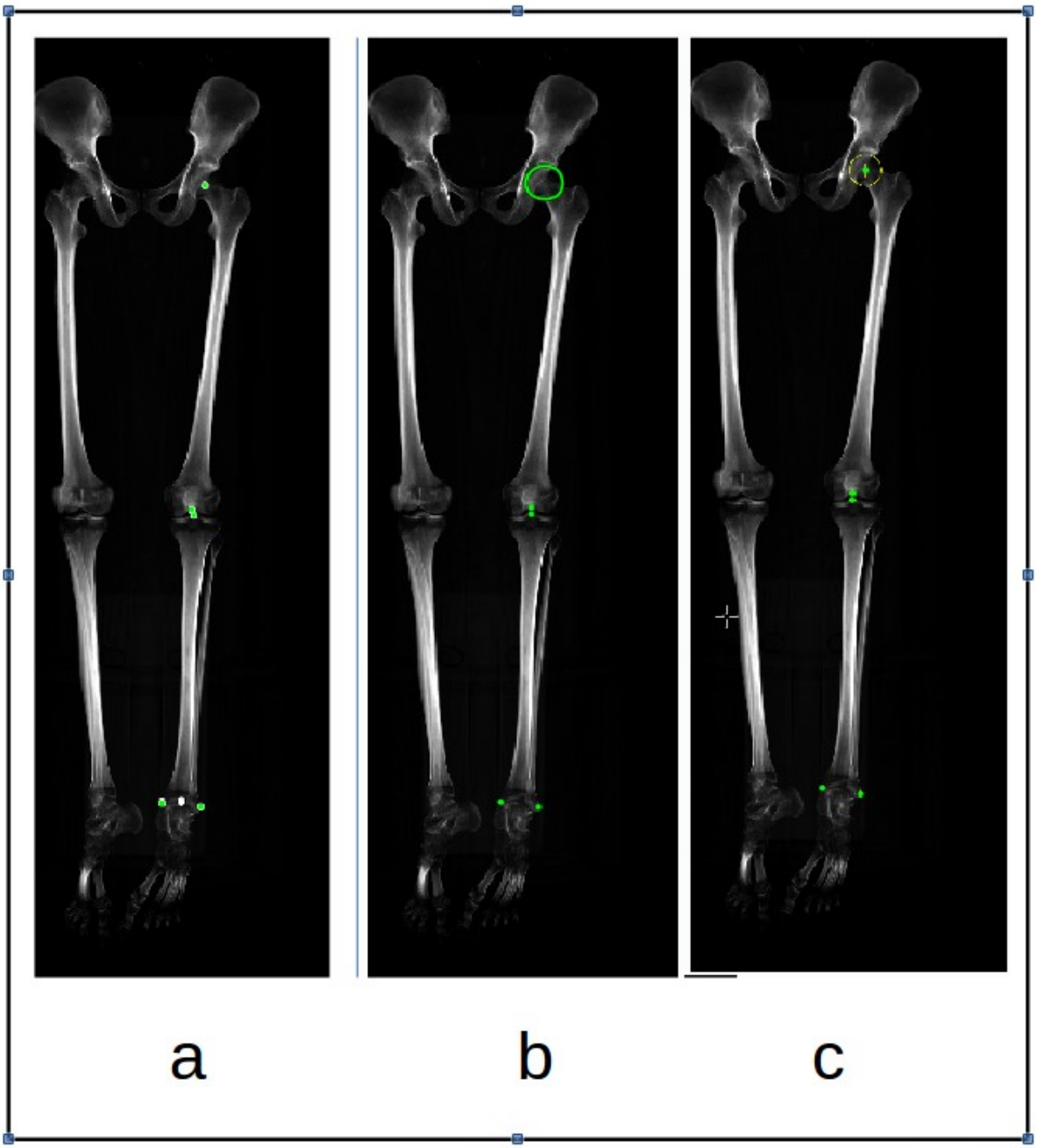

Figure 2: DRRs annotated with the five landmark points. (a) shows the landmark points in the groundtruth image. (b) and (c) show the user marked landmark points as green dots and circles.